Advanced Reliability Studies on III-V HEMTS using Low Frequency Noise Spectroscopy

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Physical Origin of Noise

Ramo's theorem describes the coupling between microscopic electronic motion and the measured current at a contact as

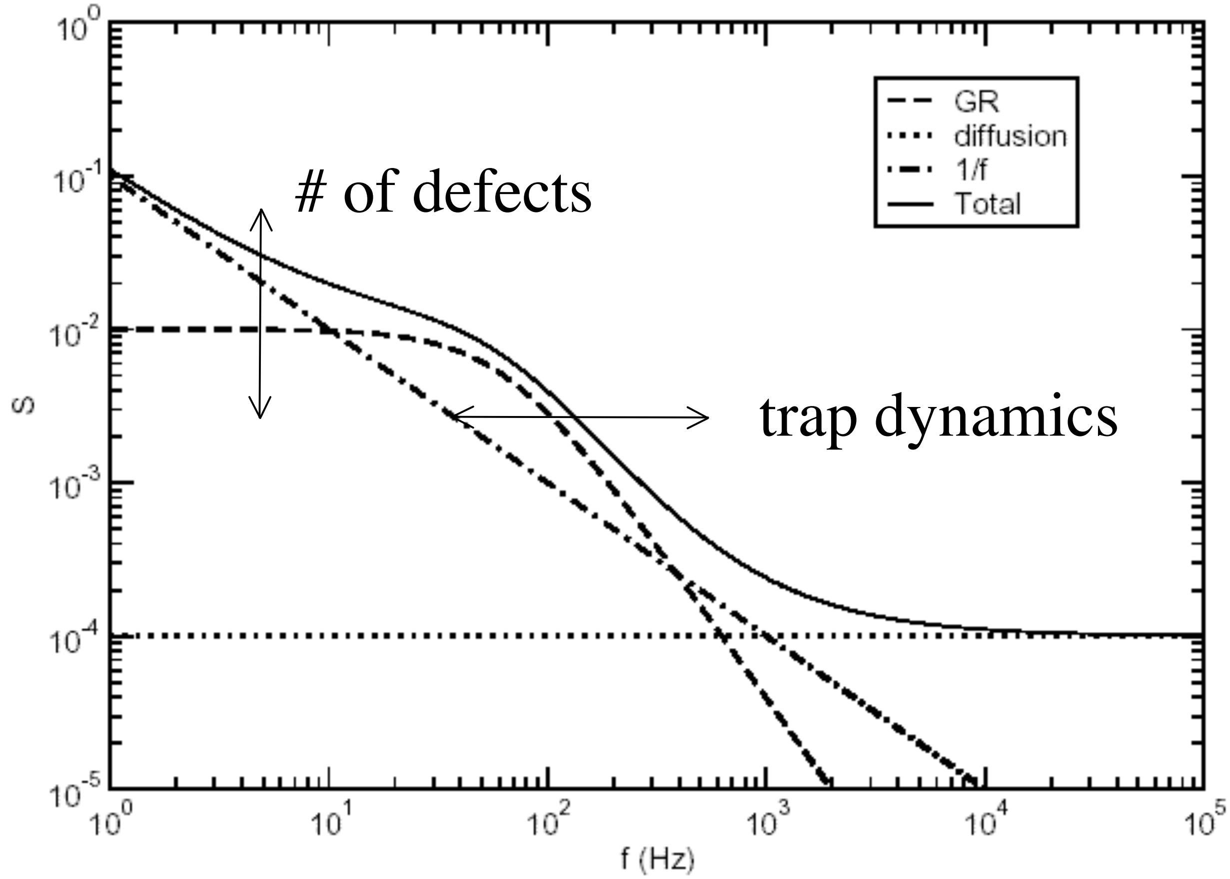
$$I(t) = \tfrac{q}{L}\sum_{k=1}^{N(t)} v_k(t)$$

where N(t) is the number of carriers, $v_k(t)$ the instant carrier velocity, and L the contact spacing.

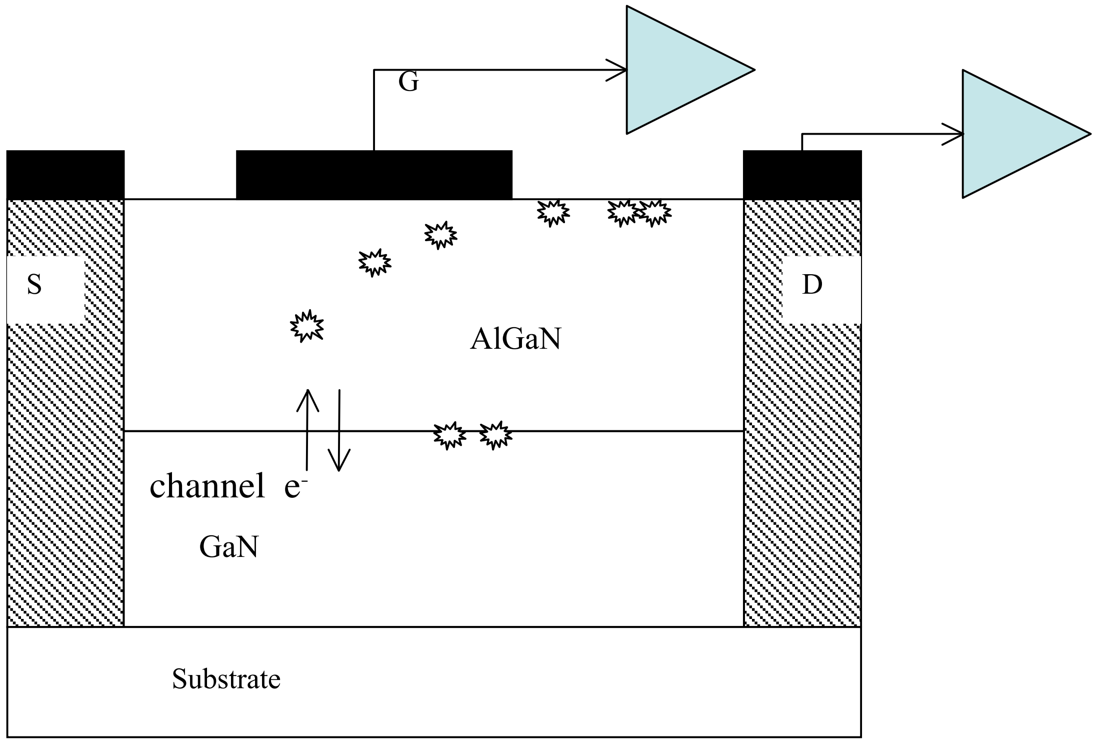
Electron trapping/detrapping in defects will cause N(t) to fluctuate and thus I(t) at the contact resulting in a Lorentzian spectral density noise signature

$$S(f)= S(0)/(1+(2\pi f\tau_c)^2)$$

Typical Noise Spectrum

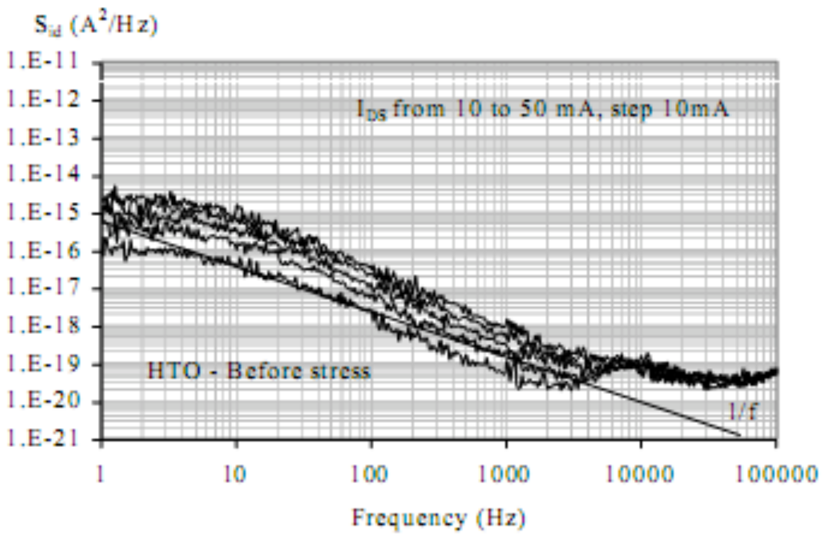


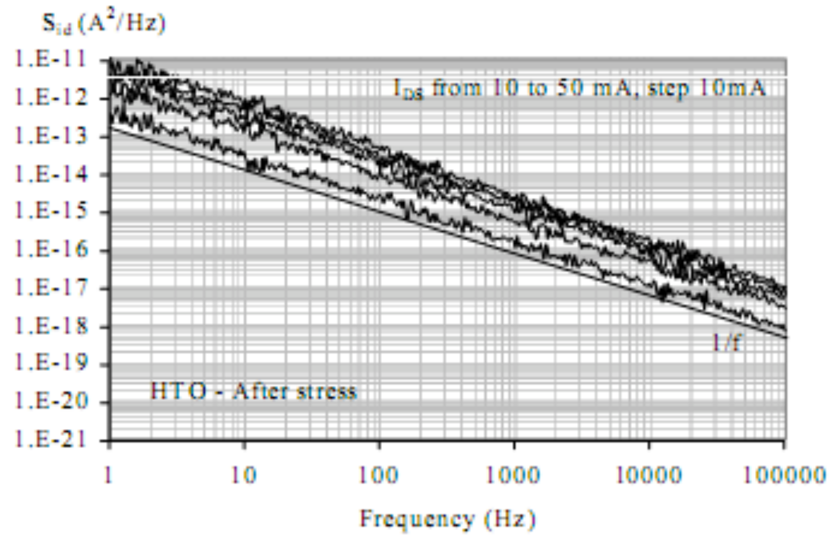
Defect Noise Sources in an AlGaN/GaN HEMT



Possible locations of hot electron or reverse piezo electric induced traps generating noise

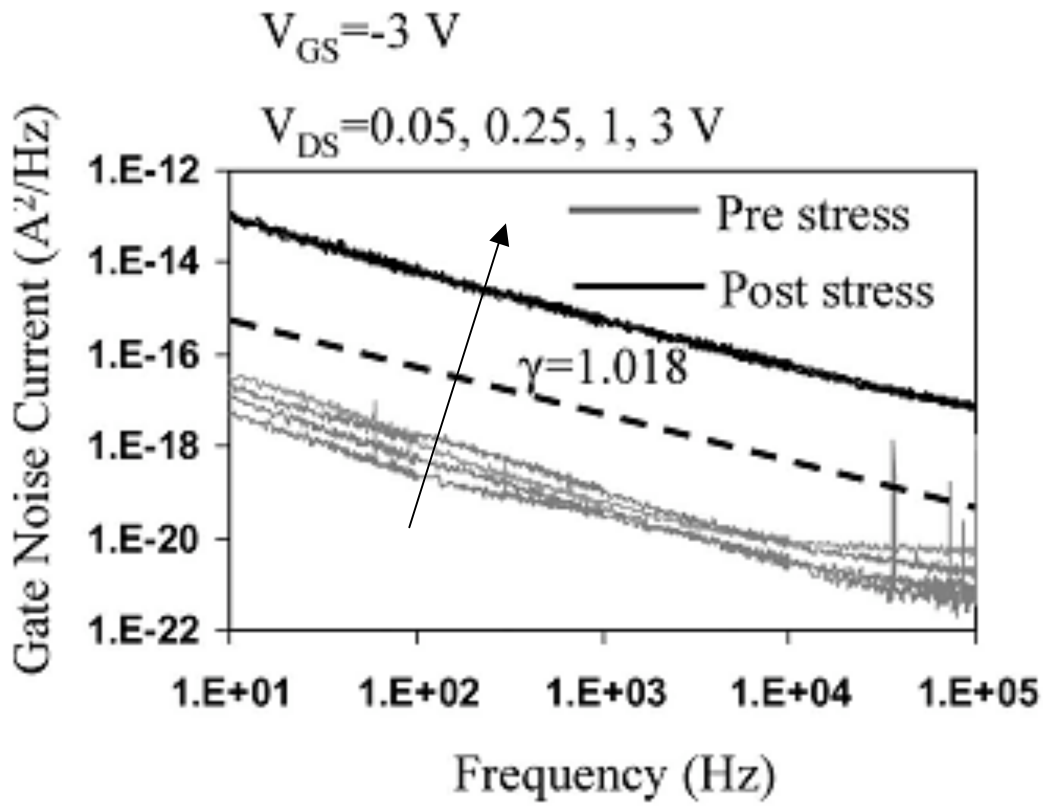
Spectral noise data stressed GaN HEMTs





- A. Sozza et. al., Microelectronics Reliability 46 (2006), 1725-1730

Low frequency noise data stressed GaN ModFET



(a)

- P. Valizadeh, D. Pavlidis, "Low-Frequency Noise Based Degradation Prediction of Al_xGa_{1-x}/GaN MODFETs", *IEEE Trans. Device Mater. Reliab., 2008, Vol. 8, No. 2. pp. 240-247*

Noise Spectroscopy

Advantages of Noise Spectroscopy

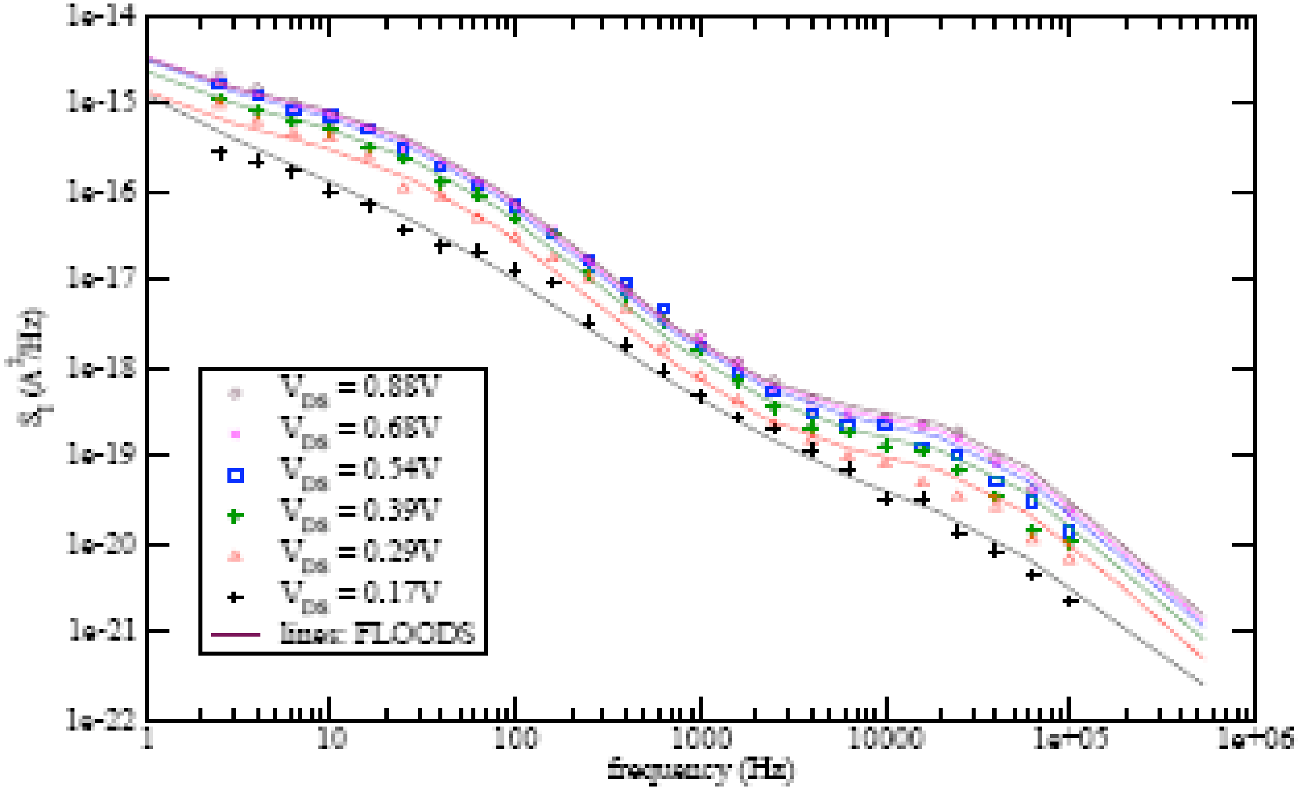
- Only defects that actually affect charge transport are probed in actual devices and under realistic bias conditions.
- Measured noise signatures provide early warning of macroscopic breakdown allowing to generate possibly a time resolved microscopic breakdown picture.

Data Extraction

- From S vs. V_D data, the lateral position and density of defects can be determined
- From S vs. V_G data the vertical position and density in the gate-stack region can be determined
- From S vs. T data, the defect activation energy can be extracted

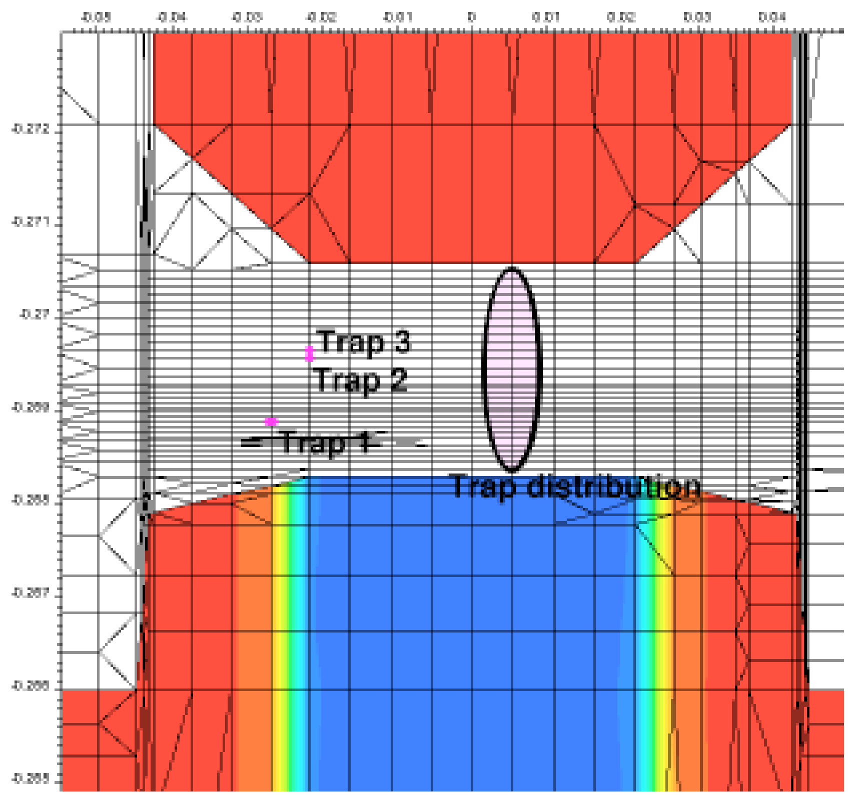
Using FLOOPS/FLOODS the localization, number and activation energy level can be determined with high precision, i.e., angstrom scale down to a single defect as we demonstrated in silicon MOSFET technology under any bias condition.

Simulated and measured noise data
3.2μm x 90nm bulk nMOSFET



Derek Martin, PhD Dissertation, UF, 2006.

3.2µm x 90nm bulk nMOSFET



Graphical depiction of oxide trap locations on mesh for simulating the low frequency noise features. Location 1 has 4 traps, locations 2 and 3 0.5 traps each. (Derek Martin, Ph.D .Dissertation, UF, 2006)

FLOOPS/FLOODS Analysis

Defect location and characterization